NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, DC 20594

December 2, 2021

Sound Spectrum Study

Specialist's Factual Report
By Sean Payne

1. EVENT

Location:	Williams, Arizona
Date:	April 15, 2021
Aircraft:	Cessna 140
Registration:	N2506N
Operator:	Private
NTSB Number:	WPR21LA166

2. GROUP

A group was not convened.

3. DETAILS OF INVESTIGATION

On April 27, 2021, the National Transportation Safety Board (NTSB) Vehicle Recorder Division received the following image recorder:

Recorder Manufacturer/Model:	**GoPro HERO 5**
Recorder Serial Number:	**C3161355736531**
Recovered Location:	**Mounted to Left Wing**

3.1. Recorder Description

For a description of the device, refer to section 3.1 of the Onboard Image Recorder Specialist's Factual Report, which can be found in the public docket for this investigation.

3.2. Recorder Damage

For a description of the device, refer to section 3.2 of the Onboard Image Recorder Specialist's Factual Report, which can be found in the public docket for this investigation.

3.3. Video Files

For a description of the video files, refer to the Onboard Image Recorder Specialist's Factual Report, which can be found in the public docket for this investigation.

The audio file examined in this report was recorded at a 48,000 Hz sample rates in 16 bits.

3.4. Sound Spectrum Study

The audio portion of the video was evaluated in an attempt to determine the engine's operating speeds during the accident flight. A spectrogram was generated showing the frequency content of the sound and how it changes over time (Figure 1). The x-axis represents elapsed time of the video and references the same time as the Onboard Image Recording – Specialist's Factual Report. The y-axis represents sound frequency in Hertz (Hz), and the color represents sound intensity.

The accident aircraft was equipped with one Continental O-200 direct drive piston engine with a two bladed fixed pitch propeller producing 100 horsepower (HP) at maximum rated RPM. The noise generated by the propeller for this type of engine configuration is generally the strongest at the fundamental blade passage frequency (BPF) with higher harmonics decaying by 5-10 decibels (dB).[1] For example, at 2750 rpm the propeller noise would be most evident at the blade passage frequency (BPF) of 91.6 Hz (eq. 1).

$$RPM = BPF\left(\frac{blades}{sec}\right) * \frac{1}{2}\left(\frac{rev}{blades}\right) * 60\left(\frac{sec}{min}\right) \qquad \text{eq. 1}$$

Figure 1 shows the lower frequency sounds generated by the engine and propeller during the video. The time of this figure is given in the x-axis and is displayed as elapsed time of the recording. The y-axis is a measure of the frequency. Correlation to local time was made by comparing the sound spectrum data to the information from the Onboard Image Recorder – Specialist's Factual Report.

Selected local time offsets have been annotated on this figure for clarity. An event consistent with an engine runup began at 19:44:46 MST, application of takeoff power began at 19:47:16 MST, the aircraft began flying outside of ground effect at 19:47:48 MST, the sound of the engine noise becoming lessened occurred at 19:48:31 MST, and the impact with terrain occurred at 19:48:43 MST.

Figure 2 shows the area of audio consistent with a runup operation in detail. Two time points are annotated, reference point 1 and reference point 2. The measured blade pass frequency at reference point 1 is 69.03 Hz and the measured BPF at reference point 2 is 80.30 Hz. The calculated BPF at each point was 2071 RPM and 2409 RPM, respectively.

Figure 3 is a Fast Fourier Transform (FFT) at reference point 1 during the area of audio consistent with an engine runup. The measured BPF at reference point 1 is

[1] Smith, M. (1989). "Aircraft Noise." Cambridge University Press.

69.03 Hz. The settings used to create the FFT are shown in the captured window. The measured BPF at this time was calculated to be 2071 RPM.

Figure 4 is a Fast Fourier Transform (FFT) at reference point 2 during the area of audio consistent with an engine runup. The measured BPF at reference point 2 is 80.30 Hz. The settings used to create the FFT are shown in the captured window. The measured BPF at this time was calculated to be 2409 RPM.

Figure 5 is a Fast Fourier Transform (FFT) at a time just after 19:47:16 when a sound was detected that was consistent with takeoff power having been applied. The measured BPF at this reference point is 80.50 Hz. The settings used to create the FFT are shown in the captured window. The measured BPF at this time was calculated to be 2415 RPM.

Figure 6 is a Fast Fourier Transform (FFT) at time just after 19:47:48 when the aircraft had appeared to leave ground effect. The measured BPF at this reference point is 81.16 Hz. The settings used to create the FFT are shown in the captured window. The measured BPF at this time was calculated to be 2448 RPM.

Figure 7 is a Fast Fourier Transform (FFT) at a time just after 19:48:31 when a sound was detected that was consistent engine power having been reduced. The measured BPF at this reference point is 73.27 Hz. The settings used to create the FFT are shown in the captured window. The measured BPF at this time was calculated to be 2198 RPM.

Shortly thereafter, at 19:48:43 MST, the aircraft impacted terrain. The sound spectrum information just prior to impact was similar to the data reported in figure 7.

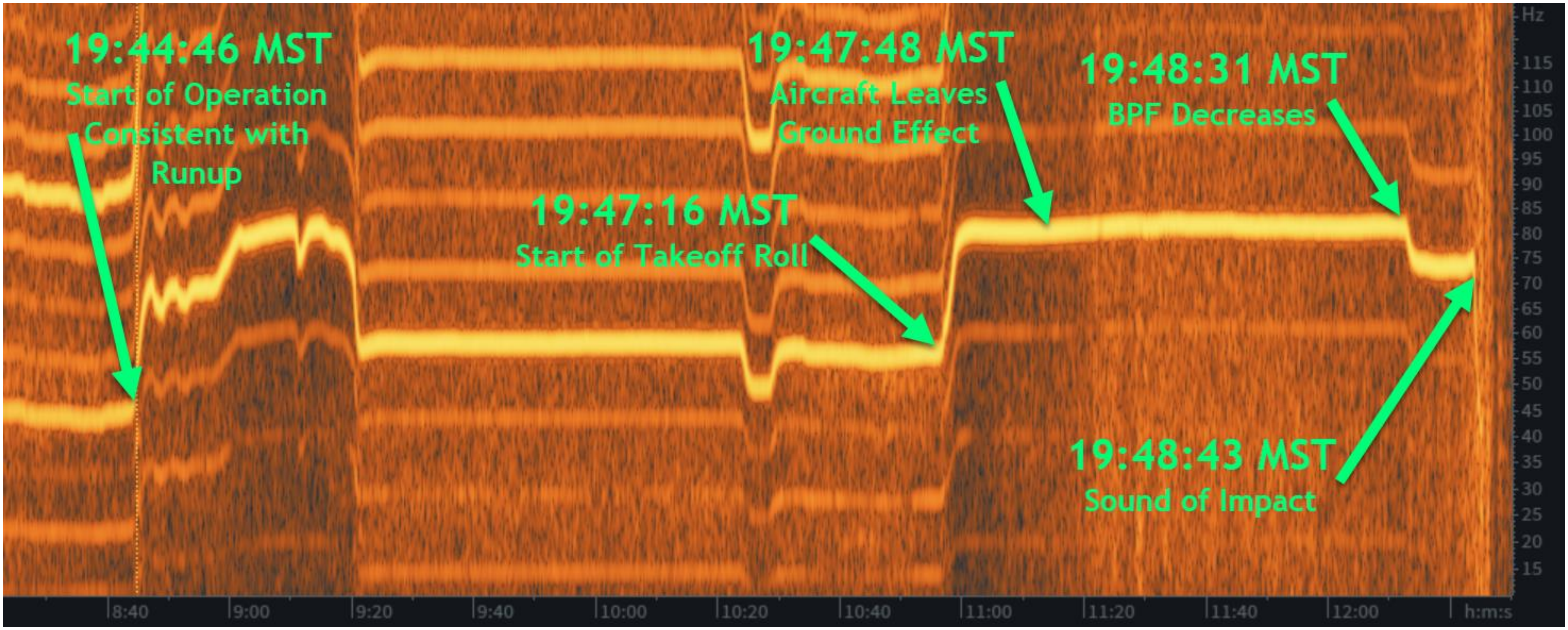

Figure 1. A sound spectrum graph of the aircraft during the entire accident flight, with relevant times from the Onboard Image Report annotated.

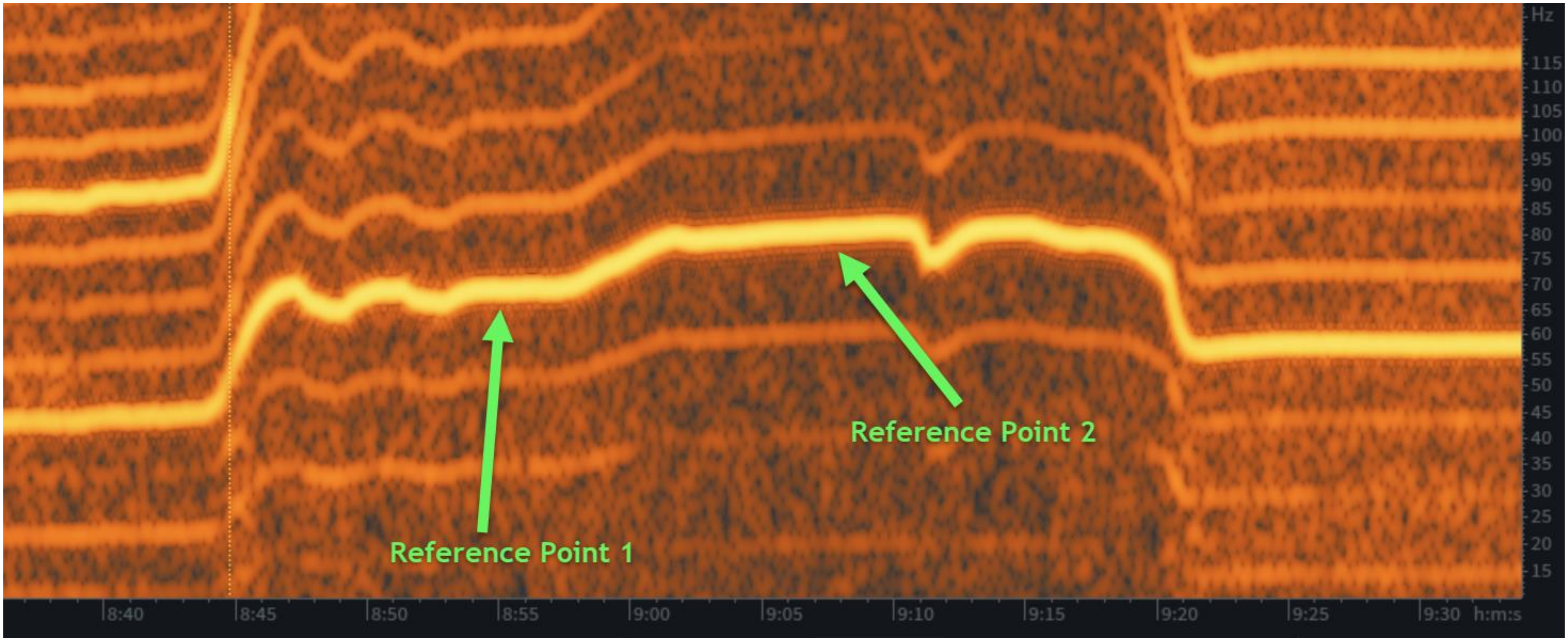

Figure 2. An expanded and annotated screenshot of the sound spectrum image consistent with an area of aircraft engine run up.

Figure 3. The blade pass frequency measured at reference point 1 as 69.03 Hz or 2071 RPM.

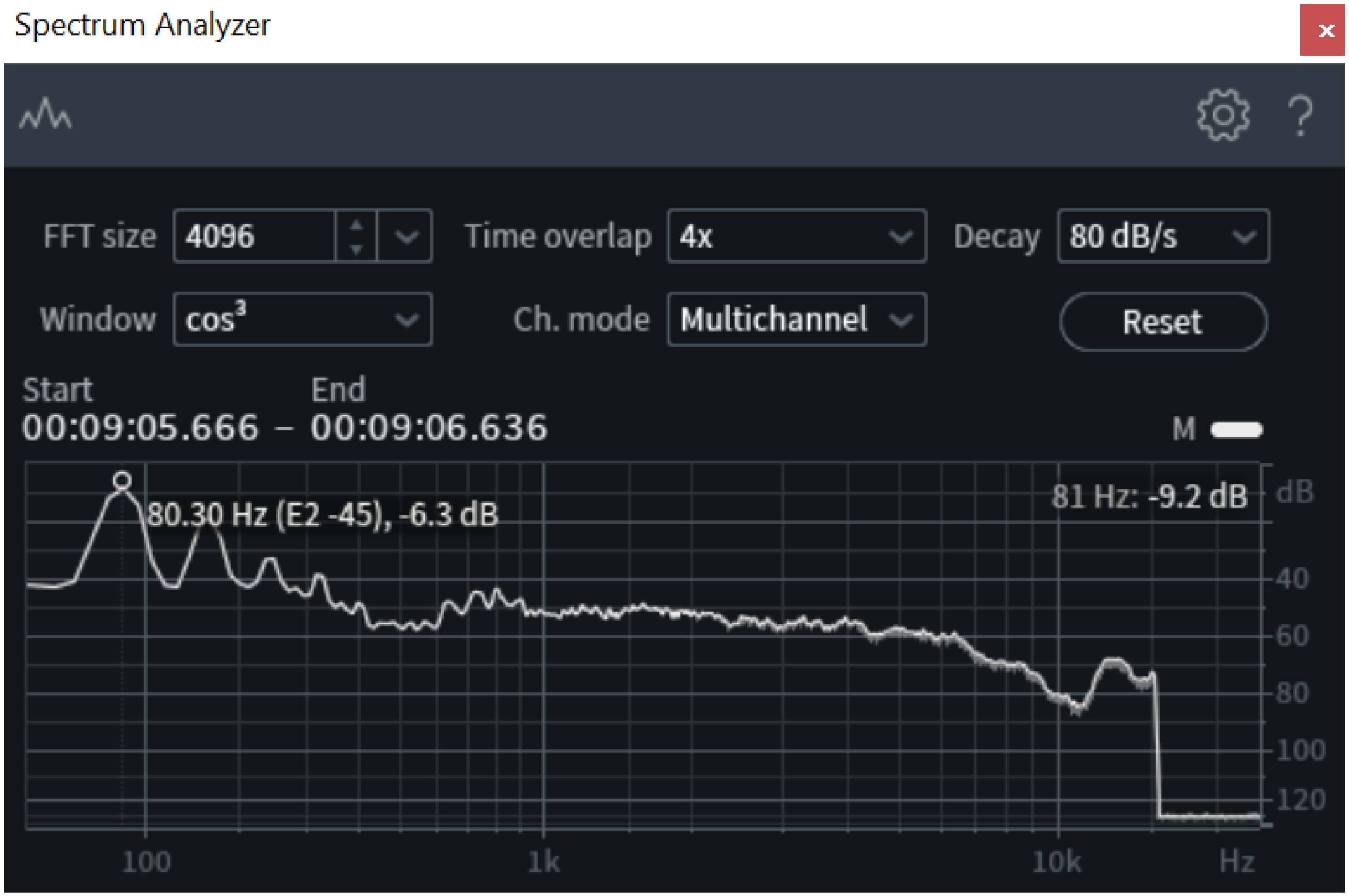

Figure 4. The blade pass frequency measured at reference point 2 as 80.30 Hz or 2409 RPM.

Figure 5. The blade pass frequency measured just after 19:47:16 MST (just after takeoff roll started) as 80.50 Hz or 2415 RPM.

Figure 6. The blade pass frequency measured just after 19:47:48 MST (just after the aircraft left ground effect) as 81.61 Hz or 2448 RPM.

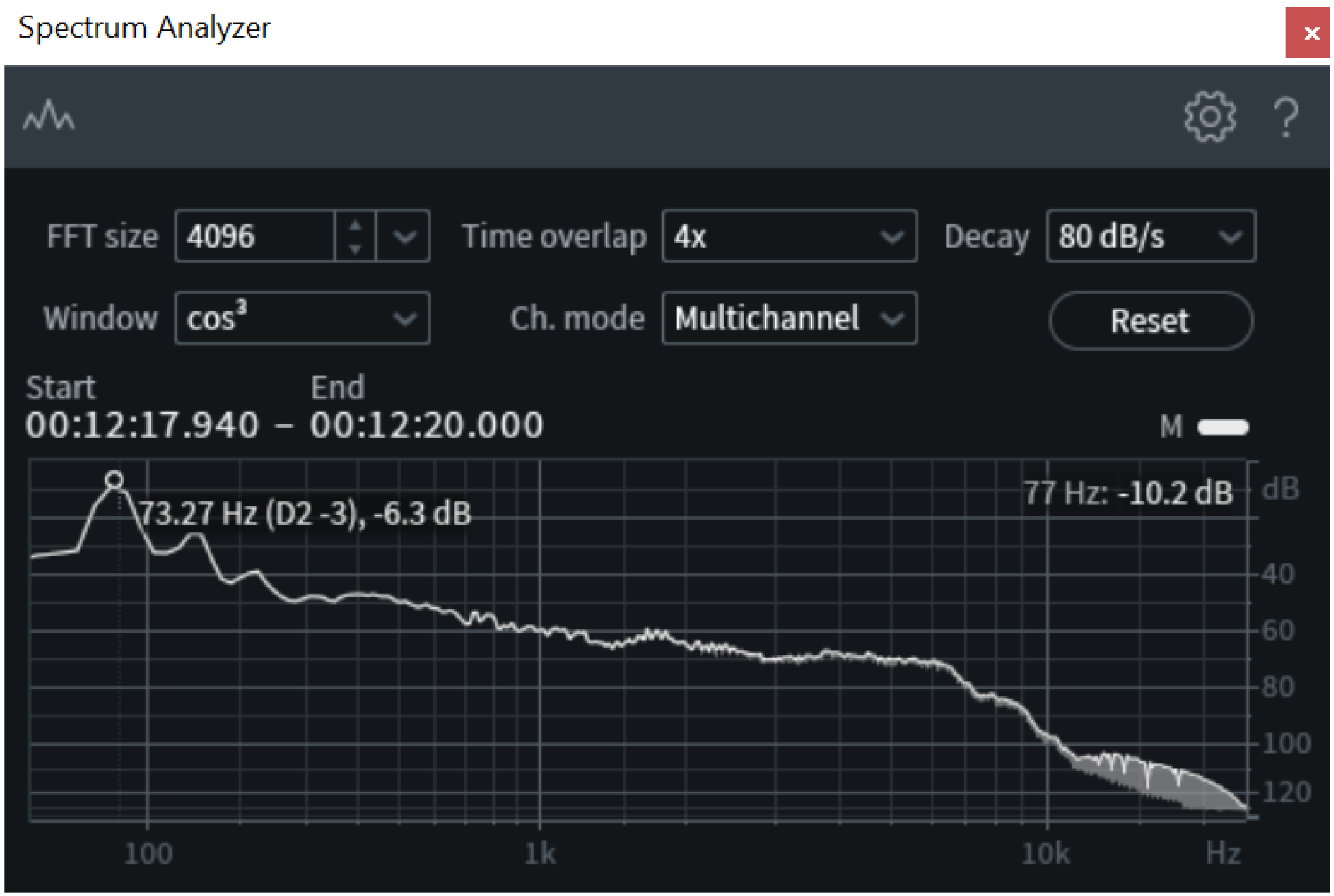

Figure 7. The blade pass frequency measured just after 19:48:31 MST (just after a sound of lessened engine power was audible) as 73.27 Hz or 2198 RPM.